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NOTES AND PROBLEMS

ON THE

ADJUSTMENT AND USE

OF

ENGINEERING INSTRUMENTS

INCLUDING

FORMS FOR FIELD NOTES

FOR THE USE OF STUDENTS IN TOPOGRAPHIC ENGINEERING.

PUBLIC
LIBRARY

BY

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Geodetic Engineering in the University of Wisconsin.*

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PREFACE.

This field manual has been prepared expressly for the author's students in surveying, in the expectation that its use would go far toward solving the problem of how to properly guide the field work of a large number of students with a limited corps of instruction. It attempts to supply the student with a clear statement of what each problem consists, the necessary equipment for its solution, together with proper methods of performing each problem and recording its field notes. The use of mimeograph copies of part of this book the past two years has proved a great saving of time, as well as otherwise aided in the thoroughness of the instruction. It is intended that this manual shall to a certain extent take the place of an instructor, but not the place of a general text book. It will add the definite directions for each problem, to the general instruction contained in the text books. Wherever reference is had to the page of text book, *Johnson's Surveying* is meant.

The fifty-five problems given constitute the required topographic work of the freshman and sophomore classes in Civil Engineering. Other students, of whom only a short general course in surveying is required, need take only the following problems: 2, 4, 6, 11, 12, 14, 18, 21, 22, 23, 24, 25, 32 and 34

All the land surveying problems given have been performed many times, and as a careful record of the results has been kept, the instructor, by means of his record, is able to point out in the field the *errors made* and thereby judge the excellence of the *instrumental work.* It is hoped that every student will put forth his best effort to secure the degree of accuracy sought, as well as earn a reputation for accuracy and industry. The acquisition of such mental habits will be at least of equal value with the technical information afforded by the exercises.

LEONARD S. SMITH.

Madison, *March* 19, 1900.

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TOPOGRAPHIC ENGINEERING.

GENERAL INSTRUCTIONS TO FIELD PARTIES.

1. Complete notes of each problem in proper form must be made during the progress of the field work.

2. The notes should be so complete as to be readily understood by any one familiar with such work.

3. The notes should be a journal of each day's field work, giving (*a*) Name of problem; (*b*) Date; (*c*) Time spent on each problem; (*d*) Name of instrument used; (*e*) Personnel of party; (*f*) A detailed report of all work.

4. No notes are to be copied from another note-book, but in general, wherever possible, *both* members of the party will record full notes.

5. In no case and for no cause shall erasures of the field-notes be made. Should any figure be erroneously entered, it should be crossed out and a correct entry made near by.

6. When the problem requires the work of two or more, each student in turn must act as chief, do the instrumental work, and take notes for a complete solution of the problem.

7. No credit will be given for field work except as it can be estimated from the field notes, and the student is urged to cultivate the habit of doing things *quickly* as well as accurately.

8. A clear and complete index of all field notes shall be prepared on first pages of field book as the work progresses.

9. Field books will be handed in for inspection every two weeks.

10. Only 4 H pencils should be used for recording.

11. Students should read over carefully the instructions before beginning a problem and see that they are fully understood.

12. *Students will be held responsible* for all equipment issued to them, and any loss or breakage must be made good to the University. Students should examine all equipment when issued and report then any injury or deficiency, in order that the responsibility may be properly fixed.

CHAPTER I.—USE OF CHAIN.

PROBLEM 1.

STANDARDIZING THE TAPE OR FINDING ITS TRUE LENGTH.

Equipment.—Chain and tape used in problems 2 and 3. A *standard* tape, spring balance, two plumb bobs, triangular scale and a strip of white card board.

Directions.—1st. Unroll the *standard* tape on the second floor of U. W. gymnasium or other suitable place, tacking a piece of white card board under the zero and 100 foot mark. With a tension of 12 lbs., as shown by the spring balance, mark with a knife edge the length on the card board of the 100 feet. Make a similar measurement with both the tape and the chain, whose true length is desired, and note carefully the difference and its sign, i. e., too long +, too short —.

2nd. Observe by several trials the changes in the length of the chain and tape by making the tension 12 lbs., then 20 lbs., etc. Record the results in note book and compute the average change in length for a variation of one pound of pull.

3rd. Hold the chain and tape clear of the floor and by use of the plumb bobs to mark the ends, find the *tension* required to make the tape and chain of standard length. Repeat the experiment three times and use the average pull in the field measurements which follow.

PROBLEM 2.

LINEAR MEASUREMENTS; CHAINING.

Equipment.—Link chain, (same as tested in Problem 1), set of marking pins; two range poles, one plumb bob.

Directions.—Set a range pole successively at the corners of U. W. Farm No. 1, and measure the length of each side as well as the diagonals radiating from Sta. *M*. Make two measurements of each line—one in each direction, lining in by eye, and taking care that the two ends of the chain are always at the same level, "breaking chain" wherever the slope requires it. Always drag the chain ahead its full length, even if it makes it necessary for the head chainman to walk back in so doing. Always place a pin at each even chain length and begin again at that point for a
ain length, keep account of the number of whole chain
y means of the pins. If the rear chainman has always

a pin at the beginning or initial station, then the number of chains at any point is the number of pins he has in his hand (not counting the pin in the ground). Use a foot rule or a pocket tape to measure the fractional part of a foot. The two measurements of each distance should check by an amount not greater than $\frac{1}{1000}$ part of the length of the line. By careful work the error can be made much less than this.

Record the results of the chaining in the field book, together with a sketch of the farm as here shown.

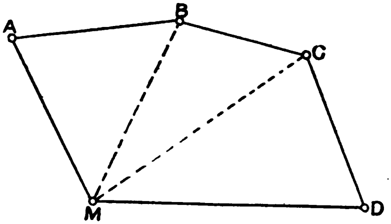

Fig. 1.

FIELD NOTES, PROBLEM 2.

From Station	To Station	Distance.	Difference in measure	Average.	Remarks.
A	*B*	228.30	$\frac{1}{2283}$	288.35	April 1, 1899.
B	*A*	228.40			Party { Head chainman. Rear chainman.
B	*C*				
C	*B*				Chain, U. W. chain, No. 2.
C	*D*				
D	*C*				Time spent on problem, 1 hr.15 min.

Office work.— Compute the area of each of the triangles *MBC*, *MCD*, *&c*, using the formula Area $=\sqrt{s\ (s-a)\ (s-b)\ (s-c)}$; where s stands for the ½ sum of the three sides of a triangle and a, b and c, are its sides.

PROBLEM 3.

USE OF STEEL TAPE.

Equipment.— 100 ft. steel tape, set of pins, two range poles, one plumb bub.

Directions.— Proceed as in Problem 2 to measure twice (in opposite directions), the sides of U. W. Farm No. 2, taking great pains to level and align the tape correctly as well as use the proper pull (found in Problem 1). Take great care in all the various operations. In good work the difference in the two measurements of any line should not exceed $\frac{1}{5000}$ part of the distance. Draw a diagram of the field on the right hand side of the field page and record notes as in Problem 2.

Caution.— In measuring lines on hill sides beginners generally hold the down hill end of tape *too low* thereby getting distances too long. This can be tested on the campus by comparison of the tape line with the water table of neighboring buildings. The horizontality of the tape can be best tested by a third observer when opposite the middle point of the tape and about 100 feet distant from it.

PROBLEM 4.

LAYING OUT RIGHT ANGLES WITH A CHAIN.

Equipment.— Link chain (or tape) and set of marking pins.

Directions.— Select an area (like the lower campus) where a square of about 200 feet on a side can be laid out. By means of the chain and the "3, 4, 5" (or multiple thereof) method lay out right angles at each corner of the square. Thus at corner *b* fix the zero of chain at *b* (with a marking pin) and have one man hold the 30-foot mark at "*m*" in the line *b a*, then with the 90-foot point held at *m* and the zero point at *b* swing the 40 mark until both sections (40 and 50 feet) are taut. The angle *m b n* will be a right angle. Produce the line *bn* to *c*, making *bc* 200 feet, then **reoperation** until *a* is reached. **Measure *a a'* and com-**

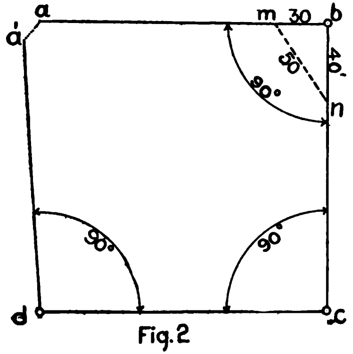

Fig. 2

pute the error of closure $= \frac{a\,a'}{\text{perimeter}} = \frac{a\,a'}{800}$. If care is used in doing the work and especially in producing the lines, the closing error $a\,a'$ may be made less than one-half of a foot.

Record results with a sketch in the field book.

PROBLEM 5.

TO CHAIN THROUGH AN OBSTACLE.

Equipment.— Same as in preceding problem.

Directions.— Select two points on the campus and lay off a right angle at b, c, d and e as shown in figure making $bc = de$. Produce $f\,e$ backwards and note the failure of the line so produced to hit b. Measure and record with sketch eb' and bb'.

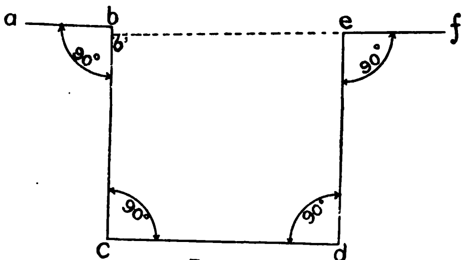

Fig.3

Field notes.— Sketches in the field book as above with statement of results, will constitute a sufficient report. The magnitude of the errors made will indicate how much reliance can be placed on such methods.

PROBLEM 6.

TO MEASURE AN ANGLE WITH A CHAIN.

Equipment.— Chain or tape, two range poles and set of pins.

Directions.—Measure all the angles in Farm I by the method suggested in the following figure, using the formula

$$\text{Sin } \tfrac{1}{2}\,\alpha = \frac{a}{2\,b}$$

If the angle should be greater. than 90° it will probably be easier to measure the supplement of the angle.

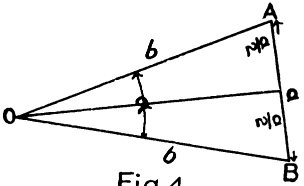

Fig.4

The following form is a convenent one for record in field book:

FIELD NOTES, PROBLEM 6.

Angle.	b	a	$\frac{a}{2b}$	½ A	A	Remarks.
D M A	50	58.71	0.734	47°-13′	94°-26′	Date ....
						Party. { ....
						Tape.
						Time.

PROBLEM 7.

TO MARK A POINT ON A HOUSE OR OTHER OBJECT NEAR A LINE OF SURVEY WHICH SHALL BE AT RIGHT ANGLES TO SAID LINE—USING A TAPE, CHAIN, OR CORD.

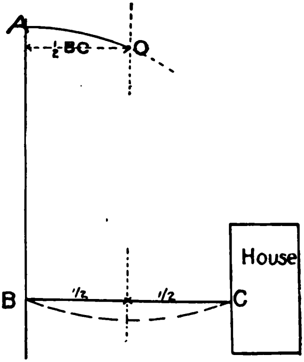

Fig. 5

Let A B be a line of survey. Let C be a house on which a transfer of point B is required at right angles to A B. Then with radius B A swing arc A O, and with ½ B C on tape, measure to arc from line A B at point O; with radius O B (= B A), and O as a center swing arc B C touching the house at C, the required point.

CHAPTER II.—THE COMPASS.

PROBLEM 8.

ADJUSTMENT OF THE SURVEYOR'S COMPASS.

I. By the maker:
   1. To make the plates perpendicular to the axis of the socket.
   2. To make the diameter through the zero graduations lie in the plane of the sights.

II. By the surveyor:
   1. To make the plane of the bubbles perpendicular to the vertical axis and therefore parallel to plates.
   2. To adjust the pivot to the center of the graduated circle.
   3. To straighten the needle.
   4. To make the plane of the sights normal to the plane of the bubbles.
   5. To remagnetize the needle.

Directions.— Write up a full report of how you tested the adjustments and manner of connecting errors found. Draw diagrams explaining method.

PROBLEM 9.

SIGHTING AND READING NEEDLE.

Equipment.— Surveyor's compass and sight pole.

Directions.— Set up the compass over some corner of Farm 1 as *Δ M* and with an east declination of 5°—00′ point and read the needle when sights are pointing at station *B*, *C*, *D*, *I* and also at spire of Capitol and University Hall.

After sighting and reading these directions by estimation of the needle to the nearest 5 minutes, change the declination a few minutes and again take the readings. From the needle bearings, the angles between the points should be computed. The discrepancies between the two sets of readings will give some idea of the degree of reliability of needle readings.

The following form for field notes is a convenient one to employ:

FIELD NOTES, PROBLEM 9.

Sta. Occ.	Station Sighted.	First Reading.	Second Readings.	Angle, 1st Determination.	Angle, 2nd Determination.	Remarks.
Δ *M*	Uni. Hall	N 75° 15′ W	N 75° 50′ W	10° 5′	10° 10′	Date.....
......	Δ *B*	N 65° 10′ W	N 65° 40′ W	....	....	Party { .. ..
......	Δ *C*.......	....	....	....	....	
......	Δ *D*	....	....	....	....	Instrument ..
......	Δ Capitol	....	....	....	....	Time ....

PROBLEM 10.

RUNNING COMPASS TRAVERSE.

Equipment.— Compass and rod, plumb bob.

Directions.—Set up the compass over some corner of Farm No 1, as Δ "*M*," then sight Δ "B" and Δ "*I*" (declination of 5° being properly set off). Then take the compass to Δ "*B*" and sight back at Δ "*M*" and forward to Δ "*C*," reading the needle at each pointing, and continuing in the same manner around the field to Sta. "*I*". Unless there is local attraction the back and fore sights should closely agree except the *E* and *W*, *N* and *S* will be interchanged. If local attraction be found determine its amount.

From these bearings, compute the angles at the several corners and compare them with the results obtained from chaining (see problem 6). The correct values for the angles of Farm 1, are $BMI = 178° \ 02'$, $MBC = 69° \ 32'$, $BCD = 152° \ 24'$, $CDE = 146° \ 49'$, $DEI = 100° \ 26'$, $EIM = 72°\text{-}47'$.

The check on the work is that the sum of the angles must equal 2 n right angles, minus 4 right angles, where n is the number of sides of the closed field.

FIELD NOTES, PROBLEM 10.

Δ occupied.	Δ sighted.	True bearing.	Angle.	Angle by chain.	Remarks.
Δ M........	Δ *I*........	S 71° 38′ E	178° 2′	178° 0′	Date.
....	Δ *B*.......	N 69° 40′ W			
Δ *B*.......	Δ *M*... ..	....	....	....	Party.
... .	Δ *C*.......	....	....	69° 15′	Instrument.
Δ *C*.......	Δ *B*.......	....	....	....	Time.
....	Δ *D*.......	....	....	152° 20′	

CARE OF INSTRUMENTS OF PRECISION.

As stated in the general instructions, students are held strictly responsible for the safe keeping and judicious use of the instruments intrusted to their care. In no case will this rule be departed from. The necessity of this rule is seen when the great cost and delicacy of such apparatus are considered. The following cautions should be read carefully. Their observance may prevent a costly accident.

It certainly does not betoken proper care to leave an instrument standing *unguarded in a street*, *road*, *or pasture*, *or in close vicinity to blasting*, or to expose it unnecessarily to the burning rays of the sun, or to dust, dampness, or rain at any time. Such carelessness must inevitably result in deterioration of the accuracy and efficiency, not to speak of the durability, of an instrument.

It should be borne in mind that there are many parts of an instrument which, *if once impaired*, cannot be restored to their original efficiency.

Legs of tripods, if fitting too loose or too tight, and dull shoes are frequent sources of falls, and loose shoes tend to make an unsteady instrument. The test of the proper degree of the tightness of the legs is this, that if the leg is raised to a horizontal position and left free, it should gradually sink to the ground. If it drops abruptly it is too loose; if it does not sink it is too tight.

When taking an instrument from its box, it is not immaterial where and how to take hold of it. To lift it by the telescope, circles, standards, or wyes is improper, and while it may not be attended at once with any serious consequences, yet it may some-

CHAPTER III.—LEVELING.

USUAL ADJUSTMENTS OF THE WYE LEVEL.

I. Preliminary focusing of eye-piece.

II. Collimation adjustment.
  (*a*) Making the vertical wire truly vertical.
  (*b*) Making line of collimation parallel to axis of telescope rings.

III. Bubble adjustment.
  Consists of making axis of bubble parallel to line of collimation by either
    (*a*) Direct or peg method, or
    (*b*) Indirect method.

IV. Wye adjustment.
  Consists of making the axis of the wyes and consequently the axis of bubble perpendicular to vertical axis.

In addition to the above all Gurley levels can have a fifth adjustment called the

V. Object Slide adjustment.
  This consists in making the optical center of the object glass move in the axis of the telescope tube.

PROBLEM 11.

TO ADJUST A WYE LEVEL.

Equipment.—Wye Level and level rod.

Directions.—First throw all parts of the instrument out of adjustment; then perform the adjustments in proper order, testing the *collimation* adjustment by *both* the direct and indirect methods. Write a complete report of how you made the tests, what discrepancies you found and how you corrected them. Use diagrams in explaining the reasons for the correction.

PROBLEM 12.

TO ADJUST A "DUMPY LEVEL."

Equipment.—Dumpy level and level rod.

Directions.—Proceed as in Problem 11, being sure to note that the first adjustment of the Dumpy level is the same as the 4th or last adjustment of the wye level as follows:

ADJUSTMENT OF THE DUMPY LEVEL.

I. To make the axis of the bubble perpendicular to the vertical axis of the instrument.

II. To make the line of collimation parallel to the axis of the bubble, i. e., the "peg method."

Record in the field book as required in Problem 11.

DIRECTIONS FOR RUNNING LEVELS.

1. A party will consist of a levelman and one rodman, both of whom will keep complete notes.
2. All levels will begin at U. W. B. M. on foundation Science Hall, near front steps, elevation 883.49 ft. above sea level, and all problems require the level line to be run in a circuit closing on the initial B. M.
3. Levelman and rodman must keep separate notes and compute differences of elevation immediately. As levelman and rodman pass, the former must read the rod himself, record results, then compute H. I. and *after* computations are made, compare results with rodman. If the results differ, each must read the rod before comparing anything but results.
4. Fore and back sights should be of equal length, as determined by pacing, and no sight should exceed 300 feet.
5. If it is impracticable to take equal back and fore sights, as soon as the steep slope is passed, take enough unequal sights to make each set balance, taking extra care to insure a correct adjustment of the level.
6. Always level the instrument exactly before setting the target. After setting it and before giving the "all right" signal examine the level bubble. After the target is firmly clamped its position should be checked by the levelman. If errors are found reset the target.
7. The level should be adjusted each day. The adjustment of the line of collimation and of the level tube is especially import-

8. Rodmen should use steel pegs with round head as turning points, never a point on sidewalk or other movable object. Keep the top of turning point free of dirt as well as the bottom of the rod.

9. In case of windy weather use plumbing levels. Long extensions of the rod are apt to introduce error into the work, and should therefore be avoided in most accurate work.

10. The limit of error should not exceed

ft.
$0.05\sqrt{\text{distance in miles}}$ (2,000 paces=one mile).

11. All Elevations are to be adjusted by distributing the closing error, as explained later, using red ink figures in the corrections.

PROBLEM 13.

DIFFERENTIAL LEVELING.

Equipment.— Level, rod and steel turning point.

Having adjusted the level, run a line of levels from S. H. B. M. (Ele. = 883.49) around No. Farm 1, closing back on initial B.M.

FORM OF FIELD NOTES, PROBLEM 13.

B. M.	+ B. S.	H. I.	− F. S.	Elevation.	Distance paces.		Remarks.
					B. S.	F. S.	
*B. M. S. H	1 141			883.49	15		*NOTE— B. M. on foundation of S. Hall N. side of east step elevation = 883.49. Instrument. Date; May 10, 1899. Party { Levelman. Rodman. Time.
		884 631	5.321	879.310		35	
	8 320				60		
		887.630	1 200	886.430		40	
		&c.	&c.				

NOTE.— (*a*) At the close of the circuit the notes should show the amount of closure error, thus:

True elevation of B. M	883.49
Elevation per line of levels	883.484
Error	.006

(*b*) At the foot of each page in field book the sum of the B. S. and F. S. readings should be computed and entered in proper column, then as a check the difference of the two sums added algebraically to the elevation to start with, should check with the elevation obtained by the field computations.

(*c*) *Divide the error of closure by the number of turning points in the circuit and apply this quotient multiplied by the number of points from beginning as a correction to the elevation of each station, entering it above the field figures using red ink.*

PROBLEM 14.

DIFFERENTIAL LEVELING.

Adjust level every day before beginning work. Run a line of levels around Farm No. 2 in the same manner as directed in Problem 13. Make an effort to obtain more accurate results than before. Use rod levels if the wind prevents the holding of the rods vertical. Be sure the bubble is in the center when the final setting of the target is made.

PROBLEM 15.

DIFFERENTIAL LEVELING.

Run a line of levels from Science Hall B. M. to B. M. on top of large stone of east portico of Washburn Observatory marked x, and return to S. H. Check on all B. Ms. which you pass on the way. Read the instructions on page 12 carefully.

PROBLEM 16.

PROFILE LEVELING.

Run a profile line from corner Science Hall down Park St. to Lake Mendota. Take reading on water level, and also on a B. M. on a three sided rock near water and east of fence. Afterward draw this profile on profile paper as directed in the class, and add a neat title. All figures on the profile which refer to elevations should be in red ink, all other figures in black. Use "Plate" A. profile paper.

Form of Field Notes, Problem 16.

Station.	+ B. S.	H. I.	— I. S.	— F. S.	Elevation.	Remarks.
S. H. B. M.	1.249				883.490	*Note B. M. on S. H.
0 + 20		884.739	3.4		881.3	Elevation = 883.49.
0 + 30			5.4		879.3	
0 + 36			7.1		877.6	Instrument.
0 + 72			6.6		878.1	Date; May 20, 1900.
0 + 90			7.6		877.1	Party } Levelman......
1 + 55			10 7		874.0	Rodman........
T. P.	0.941			10.794	873.945	Time taken.
		874.886	5.9		869.0	
			etc.		etc.	

PROBLEM 17.

DETERMINATION OF THE DIFFERENCE OF LEVEL OF LAKES MENDOTA AND MONONA.

Equipment.—Either a Wye or dumpy level, a speaking level rod, and a steel turning-point.

Directions.—Without setting the target and only reading the rod direct to the nearest hundredth of a foot, run a line of levels from the U. W. B. M. near the foot of Park street on Lake Mendota to the point where the C., M. & St. P. R. R. enters Monona. Establish a B. M. at this point on top of rail and read also the water level, then close the line of levels back on the B. M. and point of beginning.

It will afford checks on the work if intermediate temporary stations be included on the line both going and returning.

With a careful observer fully as accurate work may be done with a speaking rod without a target as with one, and the work should proceed very much faster. Record field notes as in problem 13.

PROBLEM 18.

PROFILE LEVELING.

Equipment.—Same as in problem 17.

Directions.—Run a profile line from bottom of tunnel near U. W. Central Heating Plant northwesterly to Lake Mendota, checking on B. M. at the shore and determining the lake level as well. Draw a profile of this line, and compute the elevation for every 100 feet of the bottom of a tunnel, beginning at the level of present tunnel and driven on a 2 per cent. grade. What would be the elevation of the point where such a grade would come out of the present bluff, and what would be its distance from the point of beginning? Record field notes as in Problem 13.

NOTE.—In running these profile levels use a speaking rod, reading without target to the nearest hundredth of a foot on turning points but reading only to the nearest tenth of a foot on all intermediate or profile points. Record field notes as in Problem 16.

PROBLEM 19.

Repeat problem 13, but read the *speaking rod* direct instead of by means of a target.

PROBLEM 20.

DETERMINE THE VALUE OF A DIVISION OF A LEVEL BUBBLE ON AN ENGINEER'S LEVEL.

Equipment.— Level used in previous problems, level rod and tape.

Directions.— Firmly plant the level in a shaded spot and measure a base line of about 200 feet from it to where the rod will be held, as explained in Art. 62, page 58 J. Do not depend upon the bubbles remaining the same length, but by means of its length determine the distance from the center of the tube to the point on the bubble where the graduation begins, so that all readings of either end may be from the center. Then with, say the eye end of the bubble as near the center as the graduation will allow, read and record the number of divisions of each end from the center. At same time set the target on the rod held on a turning point at the far end of the base line and record its reading. Repeat the operation with the object end of the bubble near the center, reading both ends and setting the target as before. This completes the field work which may be recorded in this manner. Base line 200 ft.:

1st Position,—Eye End 4.8; Obj. End 19.6; ½ diff. + 7.4; Rod Read. 4.913.
2nd Position,—Eye End 19.0; Obj. End 15.3; ½ diff. — 6.8; Rod Read. 4.703.

Subtracting we have 14.2 divisions of the level equal the angle whose tangent is $\frac{.205}{200}$=.00105. In a table of natural tangents this is seen to be the tangent of 3′ and 37″ or 217″. Therefore one division of the level would equal 217″ divided by $14.^{2}$ or $15.^{3}$ seconds.

CHAPTER IV.—TRANSIT WORK, ETC.

THE ADJUSTMENTS OF THE ENGINEER'S TRANSIT.

In a theoretically perfect transit instrument, the following points are established:

1. The object and eye-glasses are perpendicular to the optical axis of the telescope at all distances apart.
2. The line of collimation coincides with the optical axis.
3. The line of collimation is parallel to the telescope level.
4. The line of collimation passes through, and is perpendicular to the horizontal axis of revolution.
5. The vertical circle is perpendicular to the horizontal axis.
6. The center of its graduated arc lies in the horizontal axis.
7. The arc reads zero when the line of collimation is perpendicular to the vertical axis of the upper plate.
8. The pivots of the horizontal axis of the telescope are circles.
9. The bearings for these pivots are of the same diameter or otherwise exactly similar.
10. The line of collimation moves in a plane perpendicularly above the center of the horizontal graduated circle.
11. The horizontal axis is perpendicular to the axis of the upper plate.
12. The upper plate is perpendicular to its axis.
13. The radial lines which form the graduations of the circle and verniers are equi-distant at the same distance from the axis of the upper plate, and pass through this axis.
14. The levels of the upper plate are perpendicular to its axis.
15. The vertical axis of the upper plate coincides with the axis of the lower plate.
16. The lower plate is perpendicular to its axis.
17. The center of the vernier plate lies in the axis of the lower plate.
18. The axis of the plumb bob coincides with the vertical axis of the instrument.

Of the above points the maker attends to numbers 1, 2, 4, 5, 6, 8, 9, 11, 12, 13, 15, 16, 17, 18, as a part of the skillful manufacture of the instrument; and the engineer has no facilities for adjusting them, away from the shop. Points numbered 3, 7, 10 and 14 are attended to by the maker when the instrument leaves the shop; but owing to their liability to derangement, from accidental rough usage, the maker leaves it in the hands of the engineer to restore them at any time.

In order that the student may have clearly before him and in *proper order* the *usual* field adjustments, they are given below in tabular form:

FIELD ADJUSTMENT OF AN ENGINEER'S TRANSIT.

Preliminary.—Focus the eyepiece until the cross-wires look black and distinct, and also appear in the center of the field of view.

I. Plate Bubble Adj.—Make the axis of each plate bubble *perpendicular* to the vertical axis of the transit and therefore *parallel* to the horizontal plates.

II. Reticule Adj.—Turn the reticule until the vertical wire is truly vertical.
*III. Collimation Adj.—Make the Line of Collimation perpendicular to the horizontal axis of the telescope.
IV. Horizontal Axis Adj.—Make the horizontal axis perpendicular to the vertical axis.

V. Level Adj.—Make the axis of the telescope bubble parallel to the Line of Collimation.

VI. Vertical Circle Adj.—Make the vernier of the vertical circle read zero when the bubble is in the center of its tube.

PROBLEM 21.

ADJUSTMENT OF AN ENGINEER'S TRANSIT.

Put a transit out of adjustment, then readjust it in proper order (see tabulation above). Write a full report on the conditions found and the methods adopted for making the corrections; illustrate the report with carefully drawn diagrams. Record the instrument used and the time employed to do the work.

PROBLEM 22.

MEASURE THE INTERIOR ANGLES OF FARM NO. 1.

Equipment.—Transit and one or two transit rods.

Directions.—Always set the "A" vernier to read zero, then by the LOWER motion point and clamp on left hand station. Then loosen the top motion and turn to the right (i. e., clockwise) and point on the right hand station, the lower motion remaining clamped. Read Vernier A. For a check read the exterior angle lled the explement) and their sum should equal 360°.

---

adjustments enable the line of collimation to describe a

FIELD NOTES, PROBLEM 22.

ANGLES FARM 1.

Station Occupied.	Station Sighted.	"A." VERNIER.		Sum.	Remarks.
		Interior.	Explement		
ΔM	ΔB	0° 00′	....	....	Date, June 1, 1900.
....	Δ1	178° 02′	181° 58′	360°	Party { Transitman...
ΔB	ΔC	0° 00′	....	....	Rodman ......
....	ΔM	69° 30′	290° 30′	360°	Transit B. & B. 670.
....	etc.	etc.	etc.	etc.	Time, 1¼ hours.

PROBLEM 23.

RUNNING TRAVERSE SURVEY OF FARM NO. 2.

Equipment.—Same as in problem 22.

Directions.—Assume the azimuth from station M to spire of the capitol to be 271° 54′, thus orienting the plates; then run a traverse around Farm No. 2, at each station orienting the plate by making the "A" vernier read the same on the back sight as the "B" vernier reads on the fore sight from the station just left to the station now occupied. In other words, to compute the back-sight reading to be laid off on Ver. "A.," add 180° to the corresponding fore-sight reading. If this sum should exceed 360° then subtract 360° from it, the difference will be the back azimuth. For example, suppose the F. S. from A to B was 71°, then the B. S. reading from B to A would be by the above rule 71° + 180° = 251°. Again, suppose the forward azimuth from *B to C* were 220°, then the back azimuth would be 220 + 180 = 400°, being greater than one complete circle (360°) we subtract 360° and get 40° as the back azimuth from *C* to *B*. This is further explained by the figure.

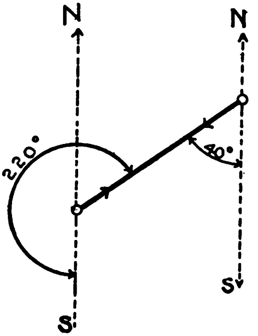

Fig. 6

FIELD NOTES, PROBLEM 23.

Station Occupied.	Station Sighted.	Azimuth.	Bearing.	Dist'nce.	Mag. Bearings.	Remarks.
....	etc.	etc.	....	....	....	....
....	Δ 2	1-0	Reduced from the Azimuth.	Taken from Freshman work.	For check.	Date ....
....	....	....				....
Δ I	Δ M	108-22				Party ....
....	....	....				....
....	Δ I	288-22				Transit ....
....	....	....				....
Δ M	Capitol	271-54	S 588° 6′ E	....	....	Time. ....

Caution.— Begin notes at bottom of page and use only every other line of book. Except where electric currents render it useless, take magnetic bearings of the lines as a check. Or after orienting the plates, turn vernier A to read 180°, then the needle *ought* to read the declination (5° E on the average). Be careful to read the right vernier, and the right part of the double vernier, viz., that part of the double vernier on the side of zero toward which the graduation increases. This is in the direction of Azimuth. The closing error in Azimuth should not exceed 2′ and with care can be made less.

PROBLEM 24.

RUNNING A STRAIGHT LINE.

Equipment.— Transit, 2 transit poles, about 10 wire nails (4 inch) and a hatchet.

Directions.— Set two transit poles "A" and "B" on University avenue so that they shall be intervisible and not less than four blocks apart. Center transit carefully over point "A" and with "B" as a foresight, set a nail at "C" on line and about a block away. Center instrument carefully over "C" and with "A" as a back sight set "D" about a block farther toward "B," and taking care to "double center" it so as to illiminate any error in the adjustment of the transit. Set up at "D" and repeat this operation always back sighting on the station just previously occupied, setting new points ahead entirely independent of station " A," until station " A " is reached where a point " A′ " should be put just opposite " A." Measure the distance from A′ to A. This will be the error of prolonging the straight line, and should not, in a half mile, exceed an inch.

This problem should illustrate the fact that a straight line can be run more accurately by fore sight than by back sight and quicker.

Make a diagram of the problem, and record all work and results in field book in a written report.

PROBLEM 25.

TO DETERMINE BY TRIANGULATION AND VERTICAL ANGLES THE HEIGHT OF AN INACCESSIBLE POINT, I. E., UNIVERSITY HALL SPIRE ABOVE THE WATER TABLE OF NORTH HALL.

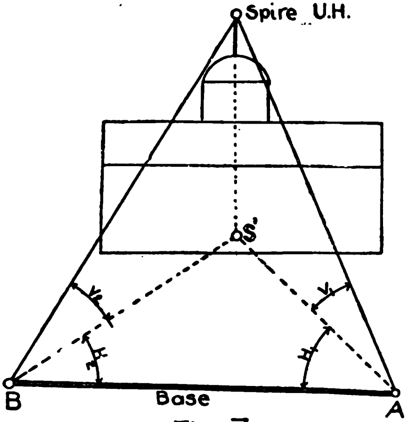

Fig. 7

Equipment.— Transit, level rod and tape.

Directions.— Measure a base line A-B between North and South Hall with its ends so placed that the spire can be seen from each. Then read and record first level readings from A to water table of North Hall, and to B and the H. I. at A, thus determining their differences of level.

Second, read the horizontal angles S′ A B and S′ B A.

Third, read the vertical angles S A S′ and S B S′ with telescope both *direct* and *reversed.* Record H. I. at both *A* and *B.* This completes the field work.

Office work.— Then in the triangle *B A S′* compute the unknown sides *B S′* and *A S′*. Then the distance S S′ in the right angle triangle S S′ A, will equal A S′ tan V which, if added to the level reading taken from A on water table will give the *elevation of bottom* of ball of spire above water table. As a check *compute this* also, using the distance B S′ and vertical angle V′.

Form of Field Notes for Problem 25.

Sta. Occu.	Sta. sighted.	Ver. A.	Dist.	Vertical Circle.			Ver. Comp.
				Direct.	Rev'd.	Ave.	
	Spire.	39° 40′	Compute	16° 18′	16° 20′	16° 19′	Compute
△B	△A	0° 00′	150 ft.	Level read.			
(H. I. = 4.)							
	Spire.	28° 24′	Compute	21° 52′	21° 54′	21° 53′	Compute
	W. T.			Level read.			
△A	△B	0° 00′	150 ft.	Level read.			
(H.I. = 4.1)							

Date, Oct. 20, 1900; Party .... Transit B. & B. 670; Time, 1 hour.

Note.— In pointing on the spire put the horizontal wire so as to be tangent to the bottom of the ball, and so the vertical wire bisects it. In the above table W. T. is an abbreviation of *water table* of North Hall.

Use only every other horizontal line in the field book. Arrange computation in field book in a neat form using a minimum number of figures, and showing the check in the two determinations of the problem as afforded by the above field work.

The filled notes begin at the bottom of the page and progress upward.

PROBLEM 26.

SIMPLE TRIANGULATION.

Equipment.— Transit, two transit poles, steel tape and nine transit hubs.

Directions.— Measure *very carefully* a base line on the E and W road near the University barn, about 800 feet long. Use standardized tape with proper pull, etc., and set permanent hubs every 100 feet, mark the exact length on a tin tack.

From the two ends of this base line *A* and *B*, determine the angles to the two ends of the base line belonging to the Student's Trigonometric Survey, as shown in the figure as *C D*. Measure eight angles for a check and having adjusted them compute the length of the line *C D*. The true length of this line is known from direct measurements with a probable error not exceeding $\frac{1}{100000}$ of of its length. Measure the angles by the repeating method. See page 504 of Johnson's Surveying. Exercise great care in centering the instrument and targets, in handling the instrument and tangent screws, and in making the pointings and readings.

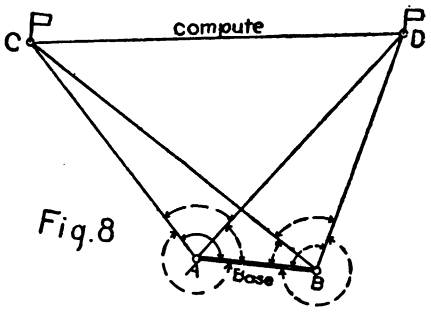

Fig. 8

PROBLEM 27.

ADJUSTMENT OF SOLAR TRANSIT.

Equipment.— Use Fauth Transit 265 and Saegmuller attachment or B and B Transit 670 and B and B solar attachment.

Directions.— Having previously thoroughly adjusted the main transit, test the two adjustments of its solar attachment, viz.:

I. To make the polar axis perpendicular to the plane of the line *of collimation* and horizontal axis of main telescope.

II. *To make line of* sight of the small telescope parallel to the *axis of its* attached bubble.

These two adjustments insure the parallelism of five lines, viz.: the two lines of sight, the axes of the two attached bubbles, and the axis of the one plate bubble (parallel to telescope); besides this the vernier of vertical circle should now read zero.

Write a report of conditions found and manner of making the above two adjustments.

PROBLEM 28.

TO DETERMINE THE AMOUNT OF THE SUN'S REFRACTION IN DELCLINATION.

Directions.— By the method explained in the following article make several determinations of the refraction at several hours of a sunny day. Check results by computing the refraction for the same times using the refraction tables on the pages 48a and 48b of Johnson's Surveying.

A SIMPLE WAY OF CORRECTING THE SUN'S DECLINATION FOR THE EFFECT OF REFRACTION.

Having focussed the eyepiece and object-glass of the transit so that a clear image of both the sun's disc and the cross-wires can be seen on the screen held behind the eyepiece (a piece of white paper held by the hand will do for a screen), set the horizontal circle of the transit to read some integral ten minutes and point on the sun by the lower motion.

The earth's diurnal motion will carry the sun across the vertical thread of the instrument. Note the time on a watch to the nearest second when the sun is tangent to the vertical wire. Keeping the lower motion clamped, unclamp the upper and turn the alidade in the direction of the sun's movement, i. e., toward the west, and set the vernier to read the next ten minutes. Note again the time when the sun is tangent to the vertical thread. Also read the vertical angle to the sun. Then if we call *n* the interval of time elapsed in seconds while the sun (really the earth) was passing through ten minutes of arc, and call *h* the vertical angle in degrees, the refraction *d*, in minutes, is given by the equation

$$d = \frac{2000}{h.\ n}.$$

Experience in using this formula has shown that its maximum *errors will not* exceed 15″ when the sun is above 10° altitude, *while its average* error is less than half this amount. As the *action correction*, as ordinarily computed, is based upon avererage conditions of temperature and barometric pressure, seldom exactly realized in any given case the writer has not been surprised to find that results obtained by the use of the above formula are quite as good as those obtained from the more complicated and pretentious formulas and tables.

A still more accurate determination of the refraction can be made by the use of the following equation:

$$d = 100 \frac{N}{n},$$

where d and n stand for same quantities as before, and N is obtained from the following table by entering it with the measured altitude of the sun as an argument.

h.	N.	Dif. for 1°.	h.	N.	Dif. for 1°.
10°	131		30°	36	
		9			1.4
15°	86		40°	22	
		5			0.9
20°	62		50°	13	
		3			0.6
25°	47		60°	7	
		2			0.4
30°	36		70°	3	

The altitude of sun need only to be observed to the nearest half degree.

30 ins

The tabulated values of N correspond to a temperature of 50° F. and a barometric pressure of ~~thirty inches~~. They may be adapted to any other temperature by diminishing d by ~~one per cent~~. for each ~~five degrees~~ by which the temperat ure exceeds 50°, or by increasing ~~one per cent~~. for each ~~five degrees~~ below 50°. 1%

This correction and the correction for variations of the barometer can usually be neglected. At great elevations, however, the barometric pressure becomes so much reduced that its variation must be taken account of, and this is done by diminishing d by ~~one per cent~~. for each ~~three hundred~~ ~~feet~~ of elevation above the sea.

5°

1%

300 ft

PROBLEM 29.

TO DETERMINE THE LATITUDE OF A PLACE EITHER WITH AN ENGINEER'S TRANSIT OR WITH A SOLAR ATTACHMENT.

Directions.— 1. *With an Engineer's transit.* Determine the refraction at a few minutes before noon, by the method used in Problem 28, or by use of the refraction tables, page 48*a*–48*b*. Then bring the vertical and middle horizontal cross-wires to bisect the image of the sun received on a card board held a few inches back of the eye-piece. As the sun approaches the meridian, his attitude will increase, reaching a maximum at culmination. The observer should follow, by means of the tangent screws, both the sun's motion in azimuth and in altitude, being careful to *stop* following when the sun turns and begins to descend. Read this maximum value of the sun's altitude (h) on the vertical circle, then we have Lat. $= (90-h) + \delta'$, where δ' is the declination of the sun *corrected for refraction* for noon. Be careful to observe the sign of δ' as it may be either + or —.

(2) *By use of the solar attachment.*—Both the large transit and its solar attachment should be in perfect adjustment. In this as well as in the following problem it is necessary to compute the apparent declination of the sun from the solar ephemeris, so the method of doing this will be first explained.

Look in the table of the Greenwich Solar Ephemeris against the date of the observation and take out the following quantities:

(*a*) The sun's apparent declination at Greenwich noon with its sign + or —, meaning north and south respectively.

(*b*) Find from a map the difference in longitude between the place of observation and Greenwich as near as one-half hour or 7½ degrees. This is + when W and — when east of Greenwich.

(*c*) To this difference of longitude expressed in time, add the time of the observation from noon, this time being + when the sun is west and — when east of the meridian.

(*d*) Multiply the hourly change, as given by the ephemeris by this result in hours, noting all signs.

(*e*) Add this product, regarding its sign, to the sun's apparent declination, as taken from the table, the result will be the sun's declination at the time of the observation. This process can be simplified in the case of Madison observations because it happens to be almost exactly 90° (= 6 hours) west of Greenwich, so that all declinations given in the Ephemeris for Greenwich noon will apply without correction for 6 A. M. Madison. Then the hourly change in declination is multiplied by the time which has elapsed
A. M. Madison and applied as a correction as in (e) above.
shington Ephemeris could have been used.]

In every case use true local time and not standard time.

In the present problem we desire the declination of the sun for noon on some certain day, say Nov. 1, 1900, or six hours after the time given in the table, the computation would be as follows:

Sun's ap. dec. Greenwich, apparent noon (Madison, 6 A. M.) for Nov. 1, 1899 = S. 14° 27′ 26″.8.
Hourly motion — 48″; i. e., sun is going south.
Time of observation 6 hrs. later.
Total amount of correction = 288″ = 4′ 48″.0.
Ap. dec. at time of observation = S. 14° 32′ 14″.8.
Refraction at time of observation = + 20″.0.
Dec. to be laid off on Ver. Cir. = S. 14° 31′ 54″.

This computation should be made before going into the field, as well as the computation of the amount of refraction at noon, unless the instrumental or watch method be used for this purpose.

Field work.— *Clamp* the line of collimation of the solar telescope to lie in the same vertical plane with the line of collination of the larger telescope by sighting some distant point with both telescopes and set the larger telescope pointing south. Then set off the declination, corrected for refraction, on the vertical circle by the following rule: For a $\left\{\begin{array}{c}\text{North}\\ \text{South}\end{array}\right\}$ declination $\left\{\begin{array}{c}\text{dip}\\ \text{elevate}\end{array}\right\}$ the south (object glass) end of the telescope until the vertical circle indicates the corrected declination. Level the solar telescope by means of its attached bubble. The instrument is now ready to make the observation.

A few minutes before the sun culminates, i. e., apparent noon, turn the instrument into the vertical plane of observer and the sun, and find the sun in the solar telescope keeping its polar and horizontal axes clamped. This is done by moving the larger telescope about its horizontal axis. The sun will increase in altitude as he approaches the meridian. Follow him in the solar telescope by means of the tangent screwn on the vertical axis of the *main transit* till this maximum elevation is reached and he starts to descend, then read the vertical angle. Then the vertical angle (h) = the co-latitude ($90° - l$) or $h = 90° - l$.

$$\therefore \text{latitude} = l = 90° - h.$$

The latitude value obtained on the campus should agree within a minute of 43° 5′.

PROBLEM 30.

USE OF THE SOLAR ATTACHMENT IN DETERMINING THE DIRECTION OF THE MERIDIAN.

Equipment.—Fauth transit 265 and Saegmuller's solar attachment or B. B. 670 and B. B. solar attachment.

Directions — By the method explained in Problem 29, compute the declination of the sun for the several hours of the day when observations are to be made. Set up transit at some corner of Farm No. 1 or 2, and determine the refraction as in Problem 28, add this *algebraically* to the declination and lay off this corrected declination on the verticle circle by the rule given in Problem 29. Lay off 47°-55′ the co-latitude as determined by Problem 29, on the vertical arc on the rignt hand side of its zero, so that when the objective of the large telescope points south the *polar* axis of the solar telescope will now point to the north pole of the heavens. The instrument is now ready for the determination proper. With the A vernier clamped at zero, turn the large telescope about its *lower* motion and the small telescope about its polar axis, until a position is reached, which enables the sun to be seen through the solar telescope, and in the center of the cross lines. The large telescope must now be on the meridian. Clamp the lower motion and the instrument is completely oriented. The accuracy of the determination can now be checked by taking the azimuth of the adjacent side of the farm whose true azimuth is known. (See Problems 21 and 22.) Careful work will give results with an error of not greater than two or three minutes.

If possible make two observations P. M. and A. M. the same time from noon. The average of the two would eliminate the errors of adjustment in the instrument.

From 8 to 10 A. M. and 2 to 4 P. M. are the most favorable times for doing this work. Care must be taken not to disturb the clamping of the *horizontal* axis of the solar telescope in the above work.

PROBLEM 31.

DETERMINATION OF THE MERIDIAN BY DIRECT SOLAR OBSERVATION.

Equipment.— Any complete engineer's transit.

Directions.— This method is fully explained in Johnson's Sur*veying, pages 103a-103d.* It would be well to determine the azimuth of the same line with this method as was determined by the preceding problem for a check. Arrange field notes and computation as shown on pages 103c-d.

OFFICE WORK,—COMPUTATIONS.

The following computations are to be made on such of the regular field days as happen to be unsuited for field work.

PROBLEM 32.

TO COMPUTE THE AREA OF FARM 2.

Directions.—Distribute your azimuth error, found in problem 22, among the various sides of the farm, then by means of the logarithmic traverse tables, pages 764-771 of Johnson's Surveying, compute the latitude and longitude differences of each of the courses. This work should balance with a limit of error not exceeding $\frac{1}{1000}$. Arrange work as shown on page 206 of Johnson's Surveying and having balanced the latitude and longitude differences by rule 3. p. 201, compute the D. M. distances and double areas. Reduce area to acres. Be careful to look out for the *signs* of the various quantities and apply frequent checks on the computation.

PROBLEM 33.

TO COMPUTE THE AREA OF FARM 1, BY THE CO-ORDINATE METHOD.

Directions.—First. Reduce your angular survey of Farm 1 (as determined by problem 22), to true Azimuth by using your own solar determination of the meridian. Second. Compute the latitude and longitude differences and balance same as in preceding problem. Third. Compute the co-ordinates of the vertices referred to X and Y axes passing through station 1. Fourth. Compute the area by the rule given on page 210. The correct area of this farm is .... acres.

PROBLEM 34.

PLATTING BY POLAR AND CARTESIAN CO-ORDINATES.

Directions.—First. Make a neat plat of Farm 1, platting by cartesian co-ördinates on a scale of about 80 feet to an inch. The map should have the co-ördinate axes drawn in red ink, and a neat tabulation of the various co-ördinates should appear on the map. Second. Make a plat of Farm 2, by polar co-ördinates, *i. e.*, by distances and bearings. Note the amount of error in closing as the error of platting only, since the farm was previously balanced. Third. Put on the plat a plain neat title telling what and *where it is, scale,* by whom and when surveyed and a north *point to show* direction. The map should also show the length *and bearing of* each line, and the total area.

PROBLEM 35.

DETERMINATION OF THE CONSTANTS OF THE POLAR PLANIMETER.

(1.) The circumference of the wheel.
(2.) The zero circumference.
(3.) The length of arm such that an area may equal 10 *n*, where *n* is the number of revolutions of the wheel.

Each value of a constant should depend upon three trials. Write a report in the field book of your investigation, showing all your work upon which your values depend. Take pains to arrange the computation neatly and logically. See Johnson's surveying page 149.

PROBLEM 36.

USE OF THE POLAR PLANIMETER.

Determine the area of farms 1 and 2 with the polar planimeter and put your results on the map in the form of a note. Put the computation work in the field book. Make three trials and use the average result.

PROBLEM 37.

USE OF CO-ORDINATES.

Compute the bearing and length of a line connecting station M with station D using the co-ördinates of these points as previously computed. Arrange the computation in field book in neat form. The true bearing of this line is N. 0°—30' W, and its true length is 459.7 feet. The computed length and bearing should appear on the map.

PROBLEM 38.

TO CUT OFF FROM FARM 1 ONE-HALF ITS AREA BY A DIVIDING LINE DRAWN FROM STATION M; AND TO DETERMINE THE LENGTH AND BEARING OF THIS DIVIDING LINE.

Directions.—This problem is explained on page 221–3 of *Johnson's Surveying.*

Record all computations in field book or in sheets attached to *field book*. *Particular* care should be taken to use a convenient *and logical arrangement* of computation.

PROBLEM 39.

TO CUT OFF THE 10 ACRES FROM FARM 2 ADJACENT TO UNIVERSITY AVE., BY A LINE DRAWN PARALLEL TO THE LINE Δ 2 — Δ 3, AND THUS DETERMINE THE LENGTH OF THE DIVIDING LINE, AND THE LENGTHS OF THE REMAINING TWO ENDS OF SUCH A TRACT.

Directions.— This problem is explained on page 224–7 of Johnson's Surveying.

Record all computations in field book as directed in problem 38.

PROBLEM 40.

USE OF THE SEXTANT.

Directions.— (a) Test the adjustments of the sextant described on page 111.

(b) From station *M* select four well defined points — as spire of capitol, court house spire, and two church spires, then measure the six angles between these points. Make two determinations for a check. Before going into the field, sufficient study should be given to the peculiar vernier to enable the student to understand readily how to read it. Compute the smallest reading of the vernier.

(c) With an artificial horizon measure the double altitute of the sun. Check the results by reading the altitude of the sun at the same time with a transit.

PROBLEM 41.

USE OF THE PLANE TABLE.

Equipment.— Plane table, four thumb tacks, sheet of paper, triangular rule and three transit poles.

Directions.—(a) Test the adjustments of the plane table as described on page 118.

(b) Make a plane table survey of Farm 1 using the distance *B M* (= 443.4 feet) as a base line. Check the position of the vertices *C*, *D*, etc., by resection.

PROBLEM 42.

USE OF THE ANEROID BAROMETER.

Equipment.—Aneroid barometer.

Directions.—*By* the method explained on page 134–9 determine *the differences of* elevation between the U. W. bench mark on

Science Hall and the corners of farm No. 1. Record the readings both in inches of mercury column and also the corresponding (approximate) elevations from the dial, and note the discrepancies between the latter and the elevations when computed like the example on page 135. Read carefully the cautions to be observed as given on page 135, and before going into the field compare the aneroid with a standard mercurial barometer.

PROBLEM 43.

CONSTRUCTION OF THE SLIDE RULE.

Equipment.—Sheet of bristle board, triangular scale, triangles and hard pencil furnished by the student.

The Principles Explained.—The ordinary slide-rule is a combination of two logarithmic scales. Such logarithmic scales then are only graphic logarithms laid off to some convenient scale; thus in the figure

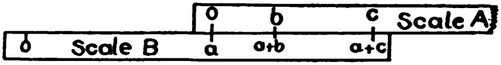

Fig. 9.

the distance o—a is made equal to the logarithm of a, and o—b equal to the logarithm of b, then if the zero of scale A be placed at a distance from the origin of scale B equal to the graphic logarithm of a, the *number* read off on scale B opposite the point b will be the product a and b. In the same way, if the product of a and c be desired with the relative position of the scales unchanged read off opposite c the number corresponding to the graphic sum of their logarithms, i. e., their product.

As the logarithm of 1 is zero the number at the origin of the scale is always 1 (10, 100, 1000). Then if ten inches represents the unit of logarithm, the number 2 (whose logarithm is .301+) would be on the scale at a distance from the origin equal to .301 times 10 inches or 3.01 inches. The student should construct two similar scales showing the graphic logarithms of 1, 2, 3, etc., up to 9. The other common operations of the rule can then be illustrated.

Sometime during the sophomore year each student in civil engineering will be required to purchase at least a cheap slide rule (cost one dollar), but he is advised to get one of the higher grade.

CHAPTER V.—TOPOGRAPHIC SURVEYING.

PROBLEM 44.

TESTING THE CAPABILITIES OF A TRANSIT.

Directions.— The best work can only be done by one who understands thoroughly the limitations and characteristics of the instruments he is using. For this reason, and also for furnishing the student with proper means for making an intelligent selection of an instrument, the following tests are outlined. All of them should be performed by each student on the instrument he is using, and a full and complete report should be made in the note book of the conditions found. The instructor will later discuss typical instruments with the class, thus enabling the student to get a fair estimate of the reliability of the different kinds of engineer's transits.

Magnifyiny Power of Telescope.—This should be of such an amount that a barely perceptible movement of the cross-hairs on an object will cause a barely perceptible movement of the bubble mounted just beneath it. Also the relation between the magnifying power and the least count of the verniers should be such that the least perceptible movement of the vernier shall cause a movement of the cross-wire on the object to be easily noticed through the telescope, and *vice versa.* A magnifying power of 24 diameters has been found well adapted for engineer's transits. To determine the magnifying power, focus the telescope on a distant object and point it toward the sky. Then measure with calipers and a fine scale the diameter of the pencil of white light emited by the eye piece i, also measure the effective diameter of the object glass G, then the magnifying power equals $\frac{G}{i}$. By the effective diameter of the object glass is meant the actual diameter less the amount cut off by the interposition of a diaphragm in the telescope tube, as is sometimes done by makers to conceal defects in the objective.

2. *Chromatic Aberration.*— "To test for this focus the telescope on a white disk and then move the object glass slowly in and out. If in the first instance a light yellow ring is seen at the edge of the object, and in the second a ring of purple light, the object glass may be considered perfect, as this proves that the most intense colors of the prismatic spectrum are corrected."

3. *Spherical Aberration.*—"For this test cover the objective with a ring of black paper thus reducing its area one-half and focus on some small well defined object. Then remove the ring and cover that part of the objective previously left open. Now notice how much the object glass must be moved in or out for distinct vision. Very little, if any, motion should be required to obtain a distinct view."

4. *Definition.*—The definition of a telescope depends upon the accuracy of the curvature of the several lenses, and upon the correct centering of the component lenses forming the objective and eye piece. For a test, focus upon small clear print at a distance of 40 feet away. It should appear as clear as when viewed by the naked eye when 8 or 10 inches away."

As a test of the centering, place a disc of white paper one-eighth of an inch in diameter in the middle of a piece of black paper and both at a distance of 30 feet away. Then if the image of the disc when a little out of focus, is equally surrounded by a uniform haze the centering is good.

Other things being equal, the lower the magnifying power the better the definition.

5. *Flatness of Field.*—"This depends largely upon the sphericity of the eyepiece. For a test draw a heavy-lined square with India ink and 8 inches on a side. Place the object at such a distance that the square shall nearly fill the field, and focus the telescope on it. If the sides appear perfectly straight the field must be flat. This quality is especially necessary in stadia measurements."

6. *Illumination.*—The brightness of an object as seen through a telescope depends upon (1) the size of the objective, (2) the polish and transparence of the lenses, (3) the magnifying power of the telescope.

PROBLEM 45.

TESTING THE SENSITIVENESS OF THE TRANSIT BUBBLE TUBES.

There are two methods of determining the angular value of one division of the bubble. One method was suggested in Problem 20; the other method is by use of a level trier like that shown in the figure. The latter method should be used in the present problem.

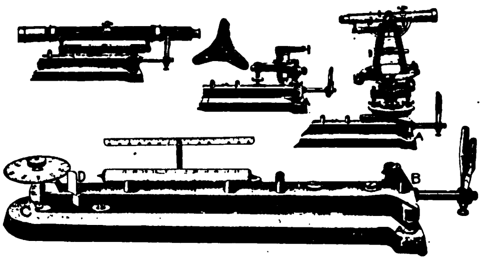

Fig. 10.

The construction of the level trier is clearly shown by the cut, Fig. 10. One end of an iron lever, 17.9 inches long, rests upon two points *A* and *B*, while the other end rests upon the point of a micrometer screw *C*, carrying a disc divided into 100 parts, which serves to raise or lower the lever. The pitch of the screw is $\frac{1}{60}$ of an inch, so that the divisions on the vertical scale *D* must be $\frac{1}{60}$ of an inch, thus measuring the amount which the lever has been raised for each complete turn of the screw. The angular movement of the lever may now be computed.

Example.— Suppose the length of arm 17.9 in., the pitch of the screw one-sixtieth of an inch and the disc to be divided into 100 parts. Through how many seconds of arc will the bar move when the micrometer screw is changed 30 divisions?

There are 206,265 seconds in the arc whose length is equal the radius.

Let $x =$ the number of seconds required; then we have

$$\frac{x}{206,265} = \frac{.005}{17.9}, \quad x = 57.6''$$

If we wish to know the radius of curvature of a level, it is necessary to measure the run of the bubble when the level has been changed a certain amount in arc, and then solve as follows:

Example.—Observed run of bubble for 30 seconds change in arc is found to be one inch. Find radius of curvature of level.

Let r = radius required:

$$\frac{r}{1 \text{ inch}} = \frac{206,265 \text{ seconds}}{30 \text{ seconds}} = 6875.5 \text{ inches}, = 572.96 \text{ ft.}$$

METHOD OF MAKING TESTS.

The level to be tested is placed in the wyes on the bar, which is raised or lowered till the bubble is at one end of the scale, or, if the level has no scale, up to the point which will be the limit of the run of the bubble in practice. The micrometer disc is then turned over equal spaces and careful notes of the run of the bubble are then taken. Having moved the bubble over its course it should be moved in the opposite direction in the same manner and the whole operation be repeated several times and, with very sensitive levels, at differing temperatures, to ensure accuracy in the results.

The mean value of all the observations may then be determined and the *value of one division of the levels expressed in minutes or seconds of arc*, as the case may be. By this same process we may find, as already shown, the radius of curvature to which the interior surface of the glass tube has been ground.

For spirit levels having no scale graduated on the tube the german silver scale graduated to 20ths of inches and attached to the apparatus is to be used as shown in the cut. For testing the levels of an Engineer's Instrument as already indicated it is not necessary to remove them, but the instrument entire can be placed directly on the Trier.

The instrument should then be leveled by its leveling screws, and the level to be examined should be brought parallel to the center line of the bar by the use of the tangent screws. (This saves much unnecessary wear on the fine micrometer screw.) This done, proceed in the same manner as explained for the unmounted spirit level. If we have the case of a wye level bubble that needs examination, the telescope and level tube may be removed from the wyes of the Instrument and placed on the wyes of the Trier, as shown in the cut. The forked arrangement at the pivotal end which can be clamped at any convenient place on the projecting rod, will tend to steady the telescope and prevent it from falling while the level is being tested.

As already indicated above, a level should be tested forward backward, and, in case of very fine spirit levels, such as are used for measuring angles, this should be repeated a number of times so as to get a considerable number of observations from which to deduce the mean value of one division in seconds of arc. In case of a level provided with an air chamber reading to single seconds of arc as a rule, it will be found necessary in making the test to keep the bubble of a constant length (a good length is two-fifths the length of the tube, excluding that of the air chamber).

Specimen sets of observations made upon levels such as are used in engineer's wye levels are given below.

Number of trials.	Micro-meter readings.	LEVEL SCALE READINGS.*		DIFFERENCES.		Length of bubble.
		A End.	B End.	A End.	B End.	
1	7	9.8	51.8	4.4	4.6	61.6
2	17	14.2	47.2	4.3	4.5	61.4
3	27	18.5	42.7	4.5	4.2	61.2
4	37	23.0	38.5	4.0	4.1	61.5
5	47	27.0	34.4	4.5	4.4	61.4
6	57	31.5	30.0	4.3	4.3	61.5
7	67	35.8	25.7	4.4	4.7	61.5
8	77	40.2	21.0			61.2
8	77	40.0	21.2	4.5	4.3	61.2
7	67	35.5	25.5	4.4	4.7	61.0
6	57	31.1	30.2	4.4	4.4	61.3
5	47	26.7	34.6	4.4	4.2	61.3
4	37	22.3	38.8	4.1	4.0	61.1
3	27	18.2	42.8	4.2	4.3	61.0
2	17	14.0	47.1	4.5	4.4	61.1
1	7	9.5	51.5			61.0
				60.9	61.1	

Mean value of differences, 4.36 20ths. of an inch.

* Level scale is graduated to 20th of an inch, reading right and left from zero at the center.

Ten divisions of micrometer screw correspond to 19.2 seconds of arc, therefore one division of scale $= \frac{19.2}{4.36} = 4.4$ seconds and one division on bubble tube (tenths of an inch) $=$ 8.8 seconds.

PROBLEM 46.

A SUBDIVISIONAL SURVEY AND MAP OF PART OF THE UNIVERSITY CAMPUS.

Equipment.—Transit, two dozen or more small wooden stakes and as many tin tacks, small ax, transit pole, set of marking pins and a standardized steel tape.

Directions.—The field work of this problem includes the accurate setting of the stakes necessary to locate two city blocks of lots and the making of all the measurements, linear and angular, required by chapter 101 of the Revised Statutes of the State of Wisconsin. This chapter should be studied before going into the field, as well as while preparing the map. A convenient place would be either on University Ave. between Brooks and Charter Sts., or on the lake shore north of the Washburn Observatory. If the latter place be selected, it may be well to introduce the arc of a circle into the boundary of the lots, in order that the lots may be of the same length and still all have equal frontage on the lake. Precautions should be taken in the use of the tape to insure an accuracy of 1 in 10,000 in the measurements. All angles should be repeated four times. Wherever possible the survey should be "tied on" to either a section corner or some block corner.

The office work consists in the preparation of a plat, on a scale of 1 inch equals 50 feet, of the above field notes and including a neat title giving, (*a*) the name of the Subdivision, (*b*) where it is located, including section, township, range, city, county and state, (*c*) scale, (*d*) by whom surveyed, (*e*) the date.

The legal certificate of the surveyor, the owner and the notary public should also be inscribed. Models and forms will be found in Appendix H or on the various plats belonging to the department.

PROBLEM 47.

TO DETERMINE THE WIRE INTERVAL AND OTHER CONSTANTS OF AN ENGINEER'S TRANSIT.

Equipment.—Transit, stadia rod, and pocket-tape.

Directions.—On the base line described in Problem 26, set up the transit $f+c$ (feet as determined by the following method), back of the end of same. Focus the object glass of the transit on a distant object and then, with pocket-tape measure the distance from the center of object glass to the cross-wires; this gives the focal length, f, of the objective. Measure also the distance from the center of the objective to the center of the horizontal axis, thus getting the constant c.

The rodman should now hold the stadia rod (which is divided into standard units) at every 100 foot hub in succession, while the transit man records the rod reading included between the upper and lower wires, as well as the lower and upper half interval readings corresponding to such distances. A rod level will aid the rodman in holding the stadia rod vertical. These readings should be repeated several times and on several days so that both afternoon and morning hours may be represented in the resulting data. If in addition to the above work two or more stakes be driven in line on either side of each hub and their distance away recorded by the rodman, and if the latter holds on all three of such points and records the order, it will have a tendency to make the stadia readings more independent and reliable, because the transit man can not know in advance what the true amount of his reading should be.

These readings should be taken between the limits of 200 and 1,200 feet, each member of the party acting as observer half the time, and recording *all* of the observations taken by the party.

In addition, the observer, the transit, date, time of day, and kind of weather should be recorded. The following is a convenient form of record:

$f = 0^m.25$
$c = 0^m.13$

PROB. 45 — INTERVAL DETERMINATION, B. & B. NO. 670.

Obs'r.	True Distance.	ROD READINGS OF			COMPUTED.			Remarks.
		Full Interval.	Lower half.	Upper half.	Full Interval.	Lower half Interval.	Upper half Interval.	
Wilson	60.96 m (200 ft.)	0.306	.154	.152	99.60	198.35	201.08	Party ....
Wilson	91.44 m (300)							May 1,1900.
Wilson	121.92 m (400)							Partly cloudy.
Wilson	152.4 m (500)							Rod, metric.
etc.	etc.	etc.	etc.	etc.	etc.	etc.	etc.	....
		Ave....	....					

Then from the stadia formula we have

$$D = K.S$$

where D is the known distance in column two, S the corresponding rod reading in the following three columns, and K the constant or interval to be determined. Transposing we have,

$$K = \frac{D}{S}.$$

The office work consists in substituting in this equation the corresponding observed values of S and D, thus securing as many determinations of K as there are such observation equations. If some of these values should differ radically from the others it would indicate either a blunder in observing the rod or in the subsequent computation. If it should be found that the former cause was responsible, the result should be disregarded in getting the final or average value of the wire interval. Great care must be exercised in this rejection of data and the advice of the instructor had best be taken. A systematic difference in the values may be expected between afternoon and forenoon observations or even between observations made at the same hour of *different* days. The important result obtained by taking an *average* interval value is that it represents average conditions and therefore will not tend to produce systematic errors into a season's work.

The rod may be read with greater ease, especially on long sights, if the sun be allowed to fall upon its face. In the case of the metric rods they should be read to tenths of the smallest graduations (which are centimeters) or to millimeters.

PROBLEM 48.

PREPARATION OF A STADIA INTERVAL TABLE.

Directions.— Having found an average wire interval, the next step is to construct a table from it, so that the stadia readings may be quickly changed to true stadia, i. e., what the rod readings would have been if the interval had been 100. Such a table would be made as follows: from the adopted interval, compute the distance for each stadia reading given in the column below marked *stadia* and having added $f + c$ to each of such computed distances, place the sums in the second column opposite the proper stadia reading: $f + c$ should not be added to readings of less than 0.1. Thus with an interval factor, K, $= 104.80$, and $f + c = 0^{m}.32$, the distance corresponding to a stadia reading $0^{m}.1$ would be $10.48 + 32 = 10.80$. Remembering that (leaving out the $f + c$), the distances are proportionate to the stadia readings, the work of computing the table can easily be done in an hour's time.

It is assumed in this explanation that the interval was determined by measuring a base line whose zero was $f + c$ in front of the center line of transit as explained on page 242. If the zero of the base line coincides with the center line of transit
b line) the construction of the table would be just the same
t *there* would be no $f + c$ additions to the column headed
e.

STADIA REDUCTION TABLE.

$f + c = 0^m.32.$ $K = 104.80.$

Stadia reading.	Distance.	Stadia reading.	Distance.
.001	.10	0.2	21 28
.002	.21	.3	31.76
.003	.31	.4	42.24
.004	.42	.5	52.72
.005	.52	.6	63.20
.006	.63	.7	73.68
.007	.72	.8	84.16
.008	.84	.9	94.64
.009	.94	1.0	105.12
.01	1.05	1 1	115 60
.02	2.10	1.2	126 08
.03	3 14	1.3	136.56
.04	4.19	1.4	147.04
.05	5.24	1.5	157 52
.06	6 29	1.6	168.00
.07	7.34	1.7	178.48
.08	8.38	1.8	188.96
.09	9.43	1.9	199.44
.10	10.80	2.0	209.92
....	....	Etc.	Etc.

PROBLEM 49.

SKETCHING TOPOGRAPHY.

Equipment.—The plats of farms 1 and 2, a small plane table without alidade, 4-H pencil and eraser.

Directions.—Transfer from the level notes to the plats the elevations of the various U. W. B. Ms. and corners of the farms. With only these data as a guide, draw a sketch map of the Upper Campus, using ten foot contours. As this is not an easy task for an experienced topographer, the beginner must expect many mistakes and should not hesitate to freely use his eraser and his legs, the former to correct, and the latter to secure, his impressions. Estimate slopes and interpolate contours between B Ms. All buildings and roads should be shown on the map in as near their true relative position as the judgment of the topographer may determine. After the map is completed in pencil, it should be compared in detail with a correct topographic map of the same area, furnished by the instructor, and the errors of the sketch carefully noted. It is not expected that the sketch will be exact at any place, but if care be taken it should not be radically wrong at any place. The benefit of the exercise lies in the education of the judgment to discover and truthfully interpret by means of contours the face of nature.

PROBLEM 50.

THE USE OF THE STADIA METHOD TO DETERMINE THE X Y AND Z CO-ORDINATES OF POINTS.

Equipment.—Complete Engineer's Transit, stadia rod, and pocket steel tape (latter furnished by the student).

Directions.—Set up the transit at any corner of farm number one and orient it by making the plates read the proper azimuth when pointing to either of the adjacent corners. The proper azimuth was determined in problem 23. 1st. Measure and record the H. I. or the distance of the horizontal axis above the station occupied. 2nd. Read the stadia rod when held vertically on the adjacent station. Ordinarily this can be done most easily by putting the lower wire of the transit at the center of the first unit, i. e., first meter or foot, and then reading the position of the upper wire. This last reading, minus unity, is the stadia intercept for that particular distance. Third, by means of the tangent screw, attached to the horizontal axis, put the *middle* cross-wire at that point on the rod equal to the H. I. already recorded in (1) and then read the vertical angle being sure to get the nearest minute, using a magnifier if necessary. For a check on this last operation, as well as for the purpose of eliminating the index error of the vertical circle, read the same vertical angle to the same point with the telescope inverted. [Of course this can be done only with a complete vertical circle.] Record the average vertical angle. At the first point occupied, take similar readings to the other adjacent station, recording the azimuth, the stadia rod reading, and the true vertical angle, being careful to note whether the letter is + or —, i. e., in elevation above or in depression below the horizontal plane. The instrument should now be taken forward to the station just sighted, the H. I. recorded, the instrument oriented on the station just left as in problem 23, and the statia rod and vertical angle read on *both* this back sight and the next fore-sight as outlined above. This will give duplicate measurements both of the true horizontal distances between the stations as well as the duplicate determinations of their *difference* of elevation.

The following form for recording field notes may be used, beginning the entries at the *bottom* of the page, and using only every other line.

FIELD NOTES FOR PROBLEM 50.

Station occupied.	Station sighted.	Azimuth.	Stadia.	Corrected stadia.	Vertical angle.	Vertical component.	Elevation.	Remarks.
⊿ B	⊿ A	48-20	0.75	75.7	0.50 D	1.08	231.59	Date.
H.I. $1^{m}.40$				(74.93)				
	⊿ B	228-20	0.75	57 7	0°-50 E	1.08	232.67	Party. {
				(89.1)				
⊿ A	⊿ M	264-44	0 883	89.3	2°-44′ D	4.23	279.36	Instrument.
H.I.$=1^{m}.49$				(88.80)				
	⊿ A	84-44	0.88	89.0	2°-44′ E	4.23	281.59	Time.
				(98.82)				
⊿ M	⊿ I	228-23	1.09	110.2	6°-14′ D	10.79	261.57	Azimuth error.

H. I. $=1^{m}.51$. Elevation of ⊿ M = $279^{m}.36$.

Only the 1st, 2d, 3rd, 4th, 6th and 9th columns are used in the field, the remainder being used for recording the office computations as explained later. The student is cautioned that in this field work he has many things to keep well before him, a single misstep being sufficient to destroy the accuracy of the entire problem. The errors most commonly made are reading the wrong vernier, using the wrong point in the venier for a zero, using the right venier but reading it the *wrong* direction and other similar large errors.

The office work connected with this problem consists first, of reducing the observed stadia readings to *corrected* stadia readings, viz., what the rod readings would have been if the wire interval of the transit had been 100. This requires the use of a stadia reduction table which the student is supposed to have already constructed in Problem 48. The method of using this table is fully explained it art. 200a, page 214, of Johnson's Surveying and need not be repeated here. The corrected stadia readings should be recorded in the column by same name. The second step consists of finding the true horizontal and vertical components of each corrected stadia reading. This may be done by the use of the Winslow Tables, page 772; thus, to compute the horizontal and vertical component of $110^{m}.2$ with a vertical angle of

6° 14 E. look in column of tables headed 6°. then opposite 14 take out the quantities 98.82 and 10.79. the former being the true horizontal component and the latter the true vertical component of 100 units at this angle. These quantities should be multiplied by the distance 110.2 and the decimal point removed two places to the left for an obvious reason. If the elevation of Station M be 916.55 feet = (279.36 meters) compute the absolute elevations of the several corners and after comparing your results with those obtained by spirit leveling (Problem 13). record final elevations in the proper columns of field notes. Also compare your horizontal distances with those obtained by the tape or chain.

NOTE: The figures in the column marked Elevation refer to the elevation of the station opposite in the second column.

PROBLEM 51.

A TOPOGRAPHIC SURVEY OF A PART OF THE UNIVERSITY CAMPUS.

Equipment.—Same as in Problem 50.

Directions.—This problem should not be attempted until after finishing Problem 50, because the latter work is introductory to the present problem. The additional features of the present problem consist in (*a*), the determination of a large number of "side shots" from each turning point occupied by the transit, sufficient in fact to determine the shape of the ground, within the limits of accuracy sought, and also sufficient to locate all buildings, roads, drives, fences, sidewalks, lake shores, etc.; and (*b*), the free hand sketching of this detail culture on the right hand side of the page. This sketch should call forth the student's best effort, for such work forms a very important part of the work of every topographer, since it is of nearly equal use with the field notes in compiling the map, the final object of the entire survey. It will be found best to draw on a single page a sketch referring to several pages of notes rather than to have a detached sketch on each right hand page for the notes opposite. This sketch should be drawn to some scale, say the width of one line about ¼ inch, equal to 25 or 50 meters and the direction of the red line on the sketch page from top to bottom taken as the North and South line of reference. The azimuths may be estimated with sufficient exactness. The sketch should show (*a*), the location of every important side shot, it being indicated by a dot and its number, (*b*), every ten-foot contour, being careful not to attempt to draw more than the immediate vicinity of the sketcher and mindful of other hints given in Problem 49, (c), the approximate ation of roads, walks, buildings, etc.

The azimuth of side shots need only be recorded to the nearest quarter degree. In reading the vertical angle, whenever possible put the *middle* crosswire at a distance from the bottom of the rod equal to the height of the instrument above the station then being occupied. Sometimes the interposition of shrubbery, etc., makes it impossible to see the rod at this particular point. In such a case read the rod at some even unit and record with the vertical angle what this unit is. At first do not try to work very fast, else errors and omissions will follow. Some time may be gained by signaling the rodman "all right" as soon as the rod is read and the horizontal wire put at proper point on the rod. While he is going to the next place the topographer can read the azimuth and vertical angle, and not feel hurried by the fact that he is delaying the work.

The proper selection of the points is a difficult task, and perhaps nothing but experience can guide. In a general way it may be said that they should be so chosen as to give the highest and lowest points, and in addition such other points, as to locate all irregularities of the terrene, as can be shown on the scale of the map which will follow the survey. Hence it is, that this scale should be known in advance of the field work. The fundamental thought which should be ever present in the topographer's mind is the simple proposition that three points determine a plane, and that by locating the terrene by points only, he conceives it to be made up of planes, being careful to take his located points sufficiently close so that when connected by planes they shall coincide with the surface, within a limit of about one-half a contour. If this be done and a good sketch drawn, the errors of the office map will be much less than the limit stated above. The sketching of the points taken, should follow the recording of their coördinates, or if this be not done at once, the position may be held in memory by a descriptive word opposite in remarks column. Having taken and sketched all the topography at the first turning point, which should either be the corner of one of the "U. W. Farms" or connected to it by a traverse, a turning point is taken in the direction of the area assigned, then occupied, the instrument oriented by backsight, and finally the topography adjacent taken as before. The turning points should be so chosen as to form a circuit, whereby the closing error in azimuth may be determined. If, after orienting the instrument at each station, the telescope be pointed to an azimuth of 180°, i. e., North, and the needle be allowed to settle in the magnetic meridian, it should read the magnetic declination, If it does not do this, either a mistake has been made in setting the vernier, or else there is a local attraction. The latter are rare in this vicinity, except where induced by electric currents, so this observation should always be taken and recorded. It gives confidence to the beginner. If an error in azimuth of greater than ten minutes be found, either by the needle or by the closure, the traverse should be re-run until the error is found. In general, the traverse line should be made to run along the top of the ridge where sights may be taken in the bottom on both sides. The stations should be selected so as to keep as near on a level or minimum grade, as under these circumstances the errors in elevation will be a minimum.

Before beginning the mapping the following office work must be done. First, the stadia readings are all to be corrected by the use of the stadia interval table belonging to the transit. Second, the traverse should be balanced on the usual blanks. Third, the co-ördinates of the turning points should be computed. Fourth, the closing errors in elevation of the circuit should be distributed, and then the elevation of all the side shots made to depend upon these corrected values. The turning points may now be platted by their co-ördinates and a north and south line being drawn through each. The side shots should be platted by means of paper or metal protractors, the number and elevation of each being noted in pencil thus $\frac{209}{84.0}$, the decimal point being the exact point. With these data on the map, and the field sketch before him the topographer will draw in the contours at five foot intervals. Much care and study should be given to this really expert work, otherwise much of the accuracy of the survey may be sacrificed. The student will find on page 276 and 277 of Johnson's some of the fundamental principles underlying contouring and which he should study carefully. Then follow the culture details of roads, buildings, etc.; finally it is inked in using the curved pen for the contours. A neat descriptive title, north point and border complete the map, which should then be traced on tracing cloth furnished by the department.

PROBLEM 52.

HYDROGRAPHIC SURVEYING.

Equipment.— Transit and stadia rod, the department rowboat and a sounding apparatus.

Directions.— A party for this work includes a transitman, who is also chief of party, a stadia man with rod in the boat, a leadsman, and at least one boatman. The work consists of locating soundings in the lake along lines normal to the shore at a distance of about 50 meters apart. Such normal lines should be run at intervals of about 150 meters. The manner of work is as follows: beginning opposite the transitman on the shore and in about 5 feet of water a sounding may be made with the stadia rod, which is then held opposite the sounding so it may be read b- [illegible] strument man who also reads the azimuth. The boat then bears away on the normal to the shore until about 50 meters farther, when a sounding is made by the lead and the rod held immediately after, in order that it may be located by the instrument man. The oarsman should take pains to keep the boat stationary until he sees the transitman's signal of "all right." At this moment the time of the sounding is recorded both by the leadsman and by the transitman (the watches having been previously compared). As an additional security against confusion of notes, each line should be given a letter, and each sounding a number, by both the land and water parties. By proper signals the transitman can keep the boat reasonably near on line. If any unusual formation should be discovered by the sounding, as a shoal, the leadsman must use his judgment regarding the position and frequency of his soundings. He should endeavor to get the deepest water between the shoal and the shore, the shoalest water on the shoal and such other soundings as, when platted, will develop its size and position. If only a gradual slope be found, the transitman will signal when the boat is about 600 meters away, for them to turn at right angles to the line just run and run parallel to the shore 150 meters to the line on which they are to return. An experienced oarsman can guess this by counting his strokes, or the proper position can be determined by the transitman's reading the rod and azimuth. The boat is now sighted to the proper point on shore, previously determined by the chief, and the same routine followed as before. When shore is reached, the transitman may desire a turning point ahead, which is then occupied and the whole return trip repeated. In case the soundings are on a river, they would be taken much more frequently and many transverse lines could be run before a new turning point would be necessary. At least twice a day the leadsman's notes should be copied into the transitman's notes. The sounding line should be compared (at the tension used in the water) daily with a standard of length, and the soundings corrected at night.

In the present problem a length of two blocks will be sufficient to illustrate the method.

The writer has recently used the above method in the survey of sixty of Wisconsin's most famous lakes and finds it the most economical of all methods for lakes of less than one mile in width.

PROBLEM 53.

RATING A CURRENT-METER.

Equipment.—Either the Ritchie Haskell direction Current-meter or the B. & B. Ellis Current-meter together with its mountings for the boat, the department row-boat, three or four batteries and connections, stop watch and register.

Directions.– Stretch the cable from the end of the University boathouse to the Raymer buoy, having previously marked every 50 feet of it by a steel tape. The party need consist of but two or three persons, a recorder in charge of the party and one or two men to pull the boat along the base line, the former being at the stern with his registering apparatus, the latter in the middle and bow. Before beginning the test, be sure that the apparatus is working uniformly and that all electric connections are made. The boatmen should understand that the success of the experiment consists largely in their keeping the boat at a uniform speed from beginning to end of the base. After a little practice this will not be difficult. Then start the boat say 30 feet from the zero of the base line, so that the regular speed will have been acquired before reaching the base line. At the moment the *end* of the bow reaches the zero of the base, a sharp "ready" should be called out by the adjacent boatman. The recorder, having previously recorded the reading of the register, immediately on hearing this signal, starts his stop watch and register apparatus by a single pressure. His duty then is to see that the register works continuously until the end of the base line is reached.

At the moment this is done, the boatman gives the same signal as before and the recorder at the same instant shuts off the current and stop watch (one motion does both). He then reads and records (a), the time used in going the length of the base line and (b), the present register number. The difference between the initial and final register numbers would of course be the total number of revolutions of the wheel. The length of base line, divided by the number of seconds used in traveling that distance, gives the true velocity of the boat. The number of revolutions of the wheel divided by the time, gives the rate of motion of the wheel. The ratio of the *velocity* of boat to the *rate* of *motion* of the wheel is the coefficient by which the registrations of the meter are changed into the velocity of the water. This ratio is not a constant, but is usually a linear function of the velocity. See equation (1) $y = ax + b$ and explanation pages 318–319. There being only two quantities to be determined a and b, only *two observation* equations are thoretically necessary, but in order *to eliminate* observation errors, etc., it has been found wise in *actice to* make a considerable number of determinations on the *line, one* group of say five observations being at low, and another similar group at high velocities. The results will prove quite instructive to the student, if some additional observations be interpolated, some at the minimum speed which will produce a revolution of the wheel, and others intermediate up to the maximum speed conveniently attainable.

A convenient form for keeping the field notes is the following:

FIELD NOTES OF PROBLEM 53.

Date .... Name of Instrument. Length of Base Line.

No. of the experiment.	No. of seconds.	Register.		No. of revolutions.	Distance.	
		Begin.	End.			
1	42	741	775	34	100 ft.	Party. Wheel 4 feet in front of boat and 2 feet under the surface of the water.
2	43	775	810	35	"	
3	42	810	844	34	"	
Etc.						

Care must be taken not to rock the boat, and especially are students warned against allowing the meter to come in contact with anything. Because of its extreme delicacy the Ellis wheel might be easily injured. The Ritchie Haskell wheel is more substantial, but is not intended to be used as a projectile. The chief of party must see to it that no risks are undertaken. The rating should be attempted only in quiet weather.

Of the two methods, graphical and analytical, of solving the observation equations, the latter is generally regarded the more accurate, and if the method given below be followed, will be even shorter than the graphical method. Before beginning the solution it would be well to plat the field notes just as taken, the revolutions of the wheel in going 100 feet as ordinates, and the time in seconds corresponding, as abscissas. If any observations are untrustworthy, the curve will show the fact by the observation falling off of the smooth line.

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A rapid method* of making the analytical solution is the following:

Let V = Velocity in feet per second.
r = The number of revolutions of the meter.
R = The number of revolutions of the meter in passing at an even velocity through 100 feet of still water.
T = Number of seconds occupied in passing the meter through 100 feet of still water at a velocity corresponding to R revolutions of the meter.
t = Number of seconds per 100 revolutions of meter.
c = The lowest velocity that will revolve the meter.

Then from the theory of the instrument

$$r \propto (V - c) \qquad (1)$$

This placed in the form of an equation is

$$r = A\ (V - c) \qquad (2)$$

Putting $A = \frac{1}{a}$, a more convenient form

$$r = \frac{1}{a}(V - c) \qquad (3)$$

Transposing we get

$$V = ar + c \qquad (4)$$

Equation (4) is an equation of a straight line, hence platting the velocities as ordinates and the corresponding revolutions as abscissas the result will be a straight line. This is the usual method, but some computation may be saved by getting the equation in a different form, thus

$$r = \frac{60\,R}{T},\ V = \frac{100}{T}$$

Substituting these values of r and V in equation (4) we obtain

$$R = \frac{100}{60\,a} - \frac{c}{60\,a}\,T. \qquad (5)$$

Now take the field notes around two velocities, separated as far as practicable from each other, as for example five trials with a velocity of about 5 feet per second and five trials with a velocity of about 1½ feet per second. Compute the average T and R of each set separately, and substitute each set in equation (5), and from the resulting two equations, solve for the quantities a and c. Now substitute for r in equation (4) its value,

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* NOTE.— This method was devised by U. S. Asst. Engr. A. O. Powell.

$$\frac{60\ R}{T},\ \text{and we have}\ V = \frac{a.\ 60.\ R}{T} + c\ \ldots.\ (6).$$

$$\text{Also since}\ \frac{R}{T} = \frac{100}{t},\ \text{if substituted in equation (6)}$$

$$\text{we have}\ V = \frac{a.\ 60.\ 100}{t} + c\ \ldots.\ (7),$$

Which is the equation sought in terms of the velocity and number of seconds per 100 revolutions; from it a table should be prepared by each party, on suitable blanks furnished by the department, giving the velocity as a function of the time taken for making 100 revolutions. These tables will be used in the field work of problem 54 and also in the two week field course in topography at the close of the year.

PROBLEM 54.

TO MEASURE THE WATER FLOWING IN THE YAHARA RIVER.

Equipment.— The Ellis current-meter mounted on a rod, stop watch, three batteries and their connections, register, record book, and, if the water be cold, a pair of rubber boots.

Directions.— Take the apparatus to the dam at the outlet of Lake Mendota near Sherman Ave. Just below the dam a place will be found where the water is confined between narrow banks and where it is sufficiently deep and swift to make the observations reliable. Stretch a piece of timber across at this point so as to be above the surface of the water and mark on it plainly at every foot for observing stations. Read and record the gauge in the lake above or on the automatic tidal gauge at the University boat house. Clear the gauging section of all stones so as to make it as even as possible, and then with a level rod take and record a sounding at every lineal foot so that the cross section may be accurately known. The wires should be long enough to allow of the batteries, etc., being left on shore. The observer now puts the meter at the mid-depth and is ready for an observation. Noting that the watch is at zero he takes the reading of the register and records it, the current is then turned on for 60 seconds when the electric current is turned off and the register read again. This operation gives one determination of the velocity at this point, then the meter is moved one station farther and the operatio repeated until the farther shore is reached. As a check it would be well to duplicate the measurements in reverse order. This may complete the field work for this party of two. The office reductions are of such a nature that they can be best explained personally and so will not be attempted here.

PROBLEM 55.

MEASUREMENT OF VOLUMES.

Directions.— Make a survey and a 5 foot contour map on tracing cloth of the present site of the new Engineering Building, and including levels of the present basements, and reference it to North Hall. Copy in red ink on the same map the contours as they were *before* the ground was disturbed. Then by the method explained in Johnson, pages, 443–448, compute the amount of dirt removed from the site.